New Methods for Detection of Fish Populations or Mapping of Fish Habitat

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LONG-TERM GOALS

The overall objective of this work is develop and test a new technique to detect and map epipelagic fishes andtheir habitat in the EEZ of Oregon and Washington. The technique combines data from satellites, aircraft, ships, and moorings. Each platform covers a unique set of spatial and temporal scales, and each instrument has its own advantages and disadvantages. A technique combining data from multiple platforms can be much more powerful than any one alone. The secondary objective is the analyze the array of spatial data collected to better understand the connection and affects of habitat and fish behavior on fish detection and distribution.

OBJECTIVES

As part of a multi-investigator team, I am involved in completing the following project objectives:

1. Refine Fish LIDAR data processing techniques and test the results by a comparison with echo sounder, airborne video, trawl, and quantified aerial survey visual observation data. Particular attention will be paid to taxa identification in aerial surveys using LIDAR depolarization and school morphology.

2. Develop a technique to combine LIDAR, echo sounder, and sampling data to produce a species-specific measure of fish distribution. The first step will be to develop a technique to combine the data into a consistent index of abundance. We will then try to develop an accurate number density estimate.

3. Develop a technique to design the most accurate fish survey for a fixed cost. This will use adaptive sampling strategies where a low-cost LIDAR survey directs an echo sounder survey to the most productive regions within the habitat. The echo sounder survey, in turn, is used to design trawl placement to get the maximum amount of information.

4. Develop GIS-based techniques to quantitatively relate the distribution of epipelagic fishes to their habitat.

5. Develop expert system for LIDAR target identification using LIDAR return characteristics, video information, and habitat data.

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14. ABSTRACT
The overall objective of this work is develop and test a new technique to detect and map epipelagic fishes andtheir habitat in the EEZ of Oregon and Washington. The technique combines data from satellites, aircraft, ships, and moorings. Each platform covers a unique set of spatial and temporal scales, and each instrument has its own advantages and disadvantages. A technique combining data from multiple platforms can be much more powerful than any one alone. The secondary objective is the analyze the array of spatial data collected to better understand the connection and affects of habitat and fish behavior on fish detection and distribution.

15. SUBJECT TERMS

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My individual tasks involved assisting with survey design (Obj 3), developing a commercial fishing industry (fishermen, spotter pilots and processors) partnership to assist with the project (Obj 5), determining survey area (Obj 3), collection of flight log and visual survey data (Obj 1), comparison of scientific lidar and acoustic data with data acquired from the commercial fishing industry (via spotter pilots) (Obj 5), and modeling the habitat data from scientific and commercial sources using GIS and spatial statistics (Obj 4).

APPROACH

The technique combines data from satellites, aircraft, ships, and moorings. Each platform covers a unique set of spatial and temporal scales, and each instrument has its own advantages and disadvantages. A technique combining data from multiple platforms can be much more powerful than any one alone. The techniques to be combined are:

1. Satellite AVHRR (Advanced Very High Resolution Radiometer) for sea surface temperature maps.

2. Satellite SeaWIFS (Sea-viewing Wide Field Sensor) for maps of primary productivity and sediment concentration.

3. Satellite SAR (Synthetic Aperture Radar) to identify fronts in the ocean that may be associated with salinity differences and changes in sea surface roughness and to map vessel activity.

4. Airborne radiometer for sea surface temperature along transects.

5. Airborne color radiometer for primary productivity along transects.

6. Airborne LIDAR for distribution and relative abundance of fish.

7. Airborne observers for geocoded fish distribution, relative abundance, and species identification.

8. Airborne video to record images of fish schools and individual fish, aiding in species identification.

9. Ship borne echosounder for concentrations of fish (research vessel).

10. Ship borne CTD for profiles and underway sampling of temperature, salinity, and density (research and commercial fishing vessels).

11. Ship borne net sampling of fish (research and commercial fishing vessels).

12. Acoustic moorings for temporal variability of fish concentrations.

13. GIS and geostatistical analyses for data analysis, integration and display.

Spatial and temporal resolutions vary with platform. The satellite instruments will provide a weekly to bi-weekly synoptic picture of the habitat, including things like the location and strength of upwelling zones, mesoscale jets and eddies, and the position of river plumes. However, except for SAR, these instruments are not able to see through clouds or into the interior of the ocean. The airborne radiometers can fly under clouds and will provide much higher spatial resolution in the area where the fish concentrations are being measured. The underway measurements from the ship provide more accurate measurements, but only along the ship track. The ship profiles will provide the depth structure at a limited number of positions. The combination of all of these will provide a detailed picture of the 3-dimensional habitat.

The airborne LIDAR will provide a large-scale view of the distribution and relative abundance of fish and plankton over the study area on temporal scales ranging from minutes to hours. Aerial observers, borrowed from the commercial fish spotter pilot pool, will provide a coarser overview and quantification of fish school distribution as well as species information. Depending on water clarity, it may not be able to see the deepest fish of some species. The echo sounder will also provide a large-scale view, although it takes days, rather than hours, to cover a significant area. However, near surface distributions of fish are generally missed due to subsurface depth of the transducer and ship avoidance behavior. Multiple aerial surveys will be performed during the acoustic survey to track any temporal changes on the scale of hours to days in the distribution during that time. Temporal variability in the density of fish will also be measured using acoustic moorings to get continuous time series at three locations. Aerial and ship-directed sampling by nets deployed from multiple vessels, research and commercial fishing, will provide validation information on the species and size composition of fish needed to interpret aerial and ship-based signal data. Again, the combination of all of these data can provide a great deal of information about the distribution of fish than any one data source alone.

All of this information will be synthesized using a GIS to analyze and visualize the relationships between the various fish species and the habitat. Numerical algorithms will be developed to quantify these relationships. We will use geostatistical analyses to determine spatial scales of autocorrelation and spatial overlap among the different components and spatial regression modeling to quantify the relationships among components. Over the last decade, many studies have used geostatistical methods to get abundance and distribution estimates for individual marine fish species, near-surface zooplankton, habitat characteristics, as well as improve survey design (e.g., Pelletier and Parma, 1994; Maravelias et al., 1996; Petitgas, 2001; Reese et al., in press). We will extend this technique to optimally combine information from LIDAR, echo sounders, and trawls.

The combination of GIS and the geostatistical method will provide additional information on spatial distribution and species assemblages along the northwest coast of North America, which is important in understanding the behavior, habitat requirements, and assemblages of the species examined and to study their relationship with the environment. By using GIS and geostatistics and community analyses it will be possible to 1) analyze and model spatial relationships among many factors at one or more points in space and time; 2) further define habitat requirements and evaluate relationships between species; and 3) display data in a way that will allow for making more effective management decisions. Comparing the distributions of marine nekton to environmental conditions should provide unprecedented detail of the coastal environment and processes involved within the Northern California Current ecosystem. The techniques developed will be directly applicable to other regions.

The LIDAR data will be processed using thresholding to remove the plankton scattering contribution, and a multi-scale expansion to aid in target identification. The multi-scale expansion will be based on the Multiresolution Median Transform (MMT) (Starck et al, 1998). The results at different scales will be compared with acoustic and sampling data to investigate the robustness of scale size for target identification. Preliminary results in the same study area produced a correlation of $R^2 = 0.97$ between LIDAR return strength, integrated over depth, and the catch of sardines when a median filter of 150 m along the flight track was applied. When the filter length was doubled to 300 m using the same data, the correlation was reduced to $R^2 = 0.35$. This suggests that the horizontal scale of the LIDAR return can be an important clue to target identification.

The echo sounder data from the ship will be binned to the same spatial resolution as the LIDAR data for direct comparison over the depth ranges where both are getting good data. Based on the data from this overlap region, a combined product will be generated that used both sets in the combined region, the LIDAR data above this region, and the acoustic data below. The acoustic data will also be expanded in a MMT and the acoustic and LIDAR data will be compared by scale size and by taxa, as identified from multi-frequency information and trawl.

The acoustic data from the three moorings at the time of each aircraft overpass will be compared with the LIDAR data. First, the profile of fish at the time of the overpass and the location of each mooring will be compared. If the profiles from the ship are affected by vessel avoidance, this should show up as a difference in the relative profiles. In this case, the LIDAR profiles provide a way to compare acoustic profiles with and without the ship present. In addition, the spatial spectrum or autocorrelation function in the vicinity of the moorings from the LIDAR will be compared with the temporal spectrum or autocorrelation function from the moorings. This result will allow us to separate out spatial and temporal effects in the variations of the returns from the ship.

Geostatistical techniques will be used in the proposed study to model and estimate the spatial structure within the data and to predict local fish abundance, along with the abiotic and biotic factors, with the use of kriging. The degree of spatial autocorrelation will be evaluated with the use of semivariograms. Once all parameters have been examined and the best-fit to the data is determined, a model will be selected. This model will then be used in the second part of the analysis, the kriging stage. During the kriging procedure, interpolation estimates will be made based on values at neighboring locations plus knowledge about the underlying spatial relationships in the data set. It is from the model fit to the semivariogram that knowledge about the underlying spatial relationships is conveyed. Kriging is superior to other means of interpolation because it provides an optimal interpolation estimate for a given coordinate location, as well as an estimate of the error for the interpolated value. After the kriging procedure is completed, a detailed map of the spatial data will be created.

Geospatial non-linear modeling will be used to evaluate the functional relationships among habitat and fish variables and to determine the best-fitting variables with the highest predictive power. Generalized additive modeling(gam; Hastie and Tibshirani, 1990; Jongman et al. 1995) is a non-parametric, non-linear regression technique and functional relationships can be determined quickly because of the functional smoothers and maximum likelihood algorithms expressed in the model and built into the software that will be used (SPlus, version 6.1, 2002, Insightful Corp). Incorporating location (as x and y coordinates) as a variable allows for geospatial modeling with gam, an example being habitat modeling of Atlantic herring by Maravelias (1999). Evaluation of gams entails examining residual deviance (D; Chambers and Hastie, 1993), deviation from the fitted responses,

takes the form -2 logeL (L = maximum likelihood) and replaces the residual sum of squares (RSS) in least-square regression (Jongman et al. 1995). The Akaike Information Criteria (AIC; Akaike, 1973) is used to determine the best model fit. A lower value denotes a better fit:
for gam, . The residual deviance (D) or RSS is "penalized" by the number of parameters (p). The dispersion parameter ( ) approximates variance of the residuals and is therefore equivalent to the linear model residual standard error (RSE) squared. The AIC value provided a quantitative measure of model fit and allowed direct comparison of gam and linear models.

WORK COMPLETED

I contributed to completion of the following tasks (described in the proposal).
Vessels were arranged to complete task 2 (performed by OSU PI Dr. Bird):

2. Deploy and retrieve acoustic moorings for field test. This task includes preparing the acoustic moorings, deployment, and retrieval. (June – August 2005)

Completed:
3. Purchase and prepare ArcPad to be used to geocoding visual observations

I prepared a NASA proposal for the acquisition of SAR:

4.Order SAR imagery and set up GIS links for acquisition of satellite data

The following imagery has been collected to date:

This task was completed in May and June of 2005; I organized a meeting with the commercial fishing industry in Astoria Oregon in May and prepared a talk about aerial remote sensing for a local workshop on Pacific sardines:

5. Field preparations and data collection for 2005 field test

b. meet, coordinate, and train with fishing industry personnel including spotter pilots and fishermen to facilitate parallel flights and net catches; install video and ArcPad/GPS in spotter aircraft (July 2005)

Acct ID	DAR_ID	User	R1_Orbit	DTK Start	Time	Beam	OBR_RT	DRF	Site
N0387EB	147798	ebrown	51029	08/14/05	2:15:21	SWB	RT	ASF	PacNWest
N0387EB	147798	ebrown	51072	08/17/05	2:27:51	SWB	RT	ASF	PacNWest
N0387EB	147798	ebrown	51179	08/24/05	14:34:38	S3	RT	ASF	PacNWest
N0387EB	147798	ebrown	51172	08/24/05	2:23:40	SWB	RT	ASF	PacNWest

I am in the process of completing this task for year 1:

6. Data processing and analysis.

So far, I have processed only the visual observer aerial data and the data from the industry including spotter pilot flight tracks and biomass estimates, catch locations, tonnage, and species/length compositions from the fishermen and processors. I have daily flight tracks, school location and size estimates, marine mammal counts and seabird counts included in the data base so far.

RESULTS

The main accomplishment was the recognition of daily movement and biomass of the 2005 target species (sardines). Sardine schools are dynamic and can migrate 10 nmi in a 24 hr period. Fishermen use spotter pilots to locate the main biomass prior to fishing operations in order to save fuel and reduce search effort. Without spotter pilots, the economics of the fishery would be in question (given the current price for the product). The implication of this is that surveys using slow moving vessels may be seriously misinterpreted because either fish are counted multiple times (if moving in the same direction as the vessel), or because the probably of encountering schools has not been considered. This years field results, which have only been preliminarily reviewed, underscore the need for addition aerial surveys and habitat modeling to guide an adaptive survey design that will reduce error due to fish school movement. We will provide aerial photographs of sardine schools to post on the ONR website.

RELATED PROJECTS

None